

## 2 System Overview

The BASINS system combines six components to provide the range of tools needed for performing watershed and water quality analyses. These interrelated components can be summarized as follows:

- National environmental databases
- Assessment tools
- Utilities
- Watershed characterization reports
- Water quality stream models
- Watershed Models and Postprocessors

A graphical representation of the BASINS components and their operating platform is provided as Figure 2.1.

The BASINS physiographic data, monitoring data, and associated assessment tools are integrated in a customized geographic information system (GIS) environment. The GIS used is ArcView 3.1 developed by Environmental Systems Research Institute, Inc. The simulation models are integrated into this GIS environment through a dynamic link in which the data required to build the input files are generated in the ArcView environment and then passed directly to the models. The models themselves run in either a Windows or a DOS environment. The results of the simulation models can also be displayed visually and can be used to perform further analysis and interpretation.

Although BASINS 3.0 remains ArcView-based, the BASINS system architecture has been completely reengineered for version 3.0. Unlike its predecessor, all customized components of BASINS 3.0, such as model interfaces, data management utilities, and watershed assessment tools, are developed as BASINS extensions, thereby providing users the capability to load only the extensions needed for their BASINS project. The new architecture also allows the system to support several levels of hardware and software sophistication. For example, users might not need to acquire Arcview's Spatial Analyst extension if they do not intend to use BASINS components that require Spatial Analyst. For the developers, it will be easier to maintain and provide updates of the individual extensions rather than issuing a new version of the entire system. This makes it also easier for the users to upgrade their system.

The modeling tools include the following:

In-stream models:

- *QUAL2E*, version 3.2, a water quality and eutrophication model.

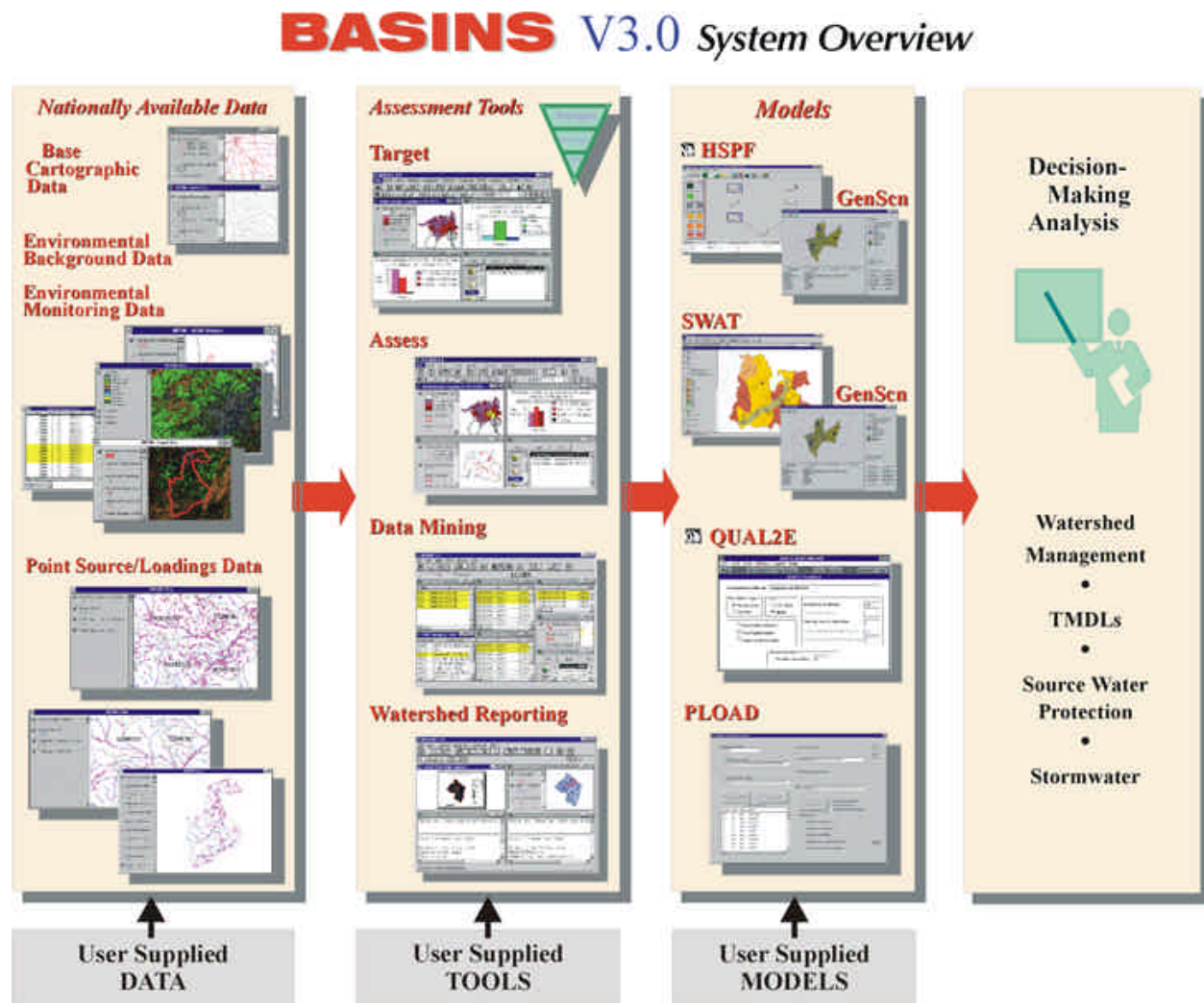


Figure 2.1 System Overview

### Watershed Models:

- *WinHSPF* is an interface to the Hydrological Simulation Program Fortran (HSPF), version 12. HSPF is a watershed scale model for estimating instream concentrations resulting from loadings from point and nonpoint sources.
- *SWAT* is a physical based, watershed scale model that was developed to predict the impacts of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land uses and management conditions over long periods of time. SWAT2000 is the underlying model that is run from the BASINS ArcView interface.

Loading models:

- *PLOAD*, a pollutant loading model. PLOAD estimates nonpoint sources of pollution on an annual average basis, for any user-specified pollutant, using either the export coefficient or simple method approach.

The BASINS GIS, which is driven by the ArcView 3.1 or 3.2 environment, provides built-in additional procedures for data query, spatial analysis, and map generation. These custom BASINS procedures allow a user to visualize, explore, query available data, and perform individualized and targeted watershed-based analyses. Some familiarity with ArcView is helpful in accessing and fully utilizing the capabilities of ArcView and the custom analytical tools. Furthermore, as users become familiar with ArcView's standard operations, environmental relationships can be further investigated using complex queries, overlays, proximity analyses, and buffer analyses.

## 2.1 Data Products

The BASINS system includes a variety of databases that are extracted and formatted to facilitate watershed-based analysis and modeling. The databases were compiled from a wide range of federal sources. The data were selected based on relevance to environmental analysis, national availability, and scale and resolution. As new data become available, updates may be distributed through the BASINS Internet site. Users are also encouraged to import locally derived data sets or higher-resolution coverages into BASINS to support the most appropriate and accurate analysis (see Section 7.2, Import). The data included within BASINS are intended to provide a starting point and data for those areas where limited site-specific information is available.

Four types of data are delivered with the BASINS analysis system:

- Base cartographic data
- Environmental background data
- Environmental monitoring data
- Point sources/loading data

### Base Cartographic Data

BASINS' base cartographic data include administrative boundaries, hydrologic boundaries, and major road systems. These data are essential for defining and locating study areas and defining watershed drainage areas. The base cartographic data products included in BASINS are presented in Table 2.1.1.

Table 2.1.1 **Base Cartographic Data**

Data Product	Source	Description
Hydrologic Unit Boundaries	U.S. Geological Survey (USGS)	Nationally consistent delineations of the hydrographic boundaries associated with major U.S. river basins
Major Roads <sup>2</sup>	Federal Highway Administration	Interstate and state highway network
Populated Place Locations <sup>2</sup>	USGS	Location and names of populated locations
Urbanized Areas <sup>2</sup>	Bureau of the Census	Delineations of major urbanized areas used in 1990 Census
State and County Boundaries	USGS	Administrative boundaries
EPA Regions	USGS	Administrative boundaries

## Environmental Background Data

Environmental background data provide information to support watershed characterization and environmental analyses. These data include information on soil characteristics, land use coverages, and the stream hydrography. This information is used in combination with modeling tools to perform more detailed assessment of watershed conditions and loading characteristics. Table 2.1.2 lists the environmental background data included in BASINS.

Table 2.1.2 **Environmental Background Data**

BASINS Data Product	Source	Description
Ecoregions Level III <sup>2</sup>	U.S. Environmental Protection Agency (USEPA)	Ecoregions and associated delineations
National Water Quality Assessment (NAWQA) Study Unit Boundaries <sup>2</sup>	USGS	Delineations of study areas
1996 Clean Water Needs Survey <sup>2</sup>	USEPA	Results of the wastewater control needs assessment by state
State Soil and Geographic (STATSGO) Database	U.S. Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS)	Soils information including soil component data and soils
Managed Area Database <sup>2</sup>	University of California, Santa Barbara	Data layer including federal and Indian lands
Reach File Version 1 (RF1)	USEPA	Provides stream network for major rivers and supports development of stream routing for modeling purposes (1:500k)
Reach File Version 3 (RF3) Alpha <sup>1</sup>	USEPA	Alpha version of Reach File 3; provides a detailed stream network and supports development of stream routing for modeling purposes (1:100K)
National Hydrography Dataset <sup>1</sup>	USGS	Spatial dataset based upon the USGS DLG and the USEPA RF3, that is more refined and expanded. Contains information about surface water features which are combined to form reaches (surface water drainage network), facilitating in routing for modeling purposes(1:100K)
Digital Elevation Model (DEM) <sup>1</sup>	USGS	Topographic relief mapping; supports watershed delineations and modeling

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(DEM) <sup>1</sup>		watershed delineations and modeling
Land Use and Land Cover <sup>1</sup>	USGS	Boundaries associated with land use classifications including Anderson Level 1 and Level 2
National Inventory of Dams <sup>2</sup>	U.S. Army Corps of Engineers and the Federal Emergency Management Agency	This dataset provides a locational map of 75,187 dams in the conterminous United States. This database shows the age/description of the dam, number of people living downstream, and some inspection information along with some locational information.

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### Environmental Monitoring Data

BASINS contains several environmental data products developed from existing national water quality databases. These databases were converted into locational data layers to facilitate the assessment of water quality conditions and the prioritization and targeting of water bodies and watersheds. These data can be used to assess the current status and historical trends of a given water body and also to evaluate the results of management actions. Table 2.1.3 lists the environmental monitoring data included in BASINS.

Table 2.1.3 **BASINS Environmental Monitoring Data**

BASINS Data Product	Source	Description
Water Quality Monitoring Stations and Data Summaries	USEPA	Statistical summaries of water quality monitoring for physical and chemical-related parameters; parameter-specific statistics computed by station for 5-year intervals from 1970 to 1994 and 3-year interval from 1995 to 1997
Bacteria Monitoring Stations and Data Summaries	USEPA	Statistical summaries of bacteria monitoring; parameter-specific statistics computed by station for 5-year intervals from 1970 to 1994 and 3-year interval from 1995 to 1997
Water Quality Stations and Observation Data	USEPA	Observation-level water quality monitoring data for selected locations and parameters
National Sediment Inventory (NSI) Stations and Database	USEPA	Sediment chemistry, tissue residue, and benthic abundance monitoring data for freshwater and coastal sediments
Listing of Fish and Wildlife Advisories	USEPA	State reporting of locations with advisories for fishing, including type of impairment
Gage Sites	USGS	Inventory of surface water gaging station data including 7Q10 low and monthly mean stream flow
Weather Station Sites	National Oceanic and Atmospheric Administration (NOAA)	Location of selected first-order NOAA weather stations
Drinking Water Supply (DWS) Sites <sup>2</sup>	USEPA	Location of public water supplies, their intakes, and sources of surface water supply
Watershed Data Stations and Database	NOAA	Location of selected meteorologic stations and associated monitoring information used to support modeling
Classified Shellfish Areas <sup>2</sup>	NOAA	Location and extent of shellfish closure areas



### Point Source/Loading Data

BASINS also includes information on pollutant loading from point source discharges. The location, type of facility, and estimated loading are provided. These loadings are also used to support evaluation of watershed-based loading summaries combining point and nonpoint sources. Potential source loading locations from hazardous waste sites and air emissions are also included. Table 2.1.4 lists the point source/loading data included in BASINS.

Table 2.1.4 **BASINS Point Source/Loading Data**

BASINS Data Product	Source	Description
Permit Compliance System (PCS) Sites and Computed Annual Loadings	USEPA	NPDES permit-holding facility information; contains parameter-specific loadings to surface waters computed using the EPA Effluent Decision Support System (EDSS) for 1990-1999
Industrial Facilities Discharge (IFD) Sites	USEPA	Facility information on industrial point source dischargers to surface waters
Toxic Release Inventory (TRI) Sites and Pollutant Release Data	USEPA	Facility information for 1987-1995 TRI public data; contains Y/N flags for each facility indicating media-specific reported releases
Superfund National Priority List Site <sup>2</sup>	USEPA	Location of Superfund National Priority List sites from CERCLIS (Comprehensive Environmental Response, Compensation and Liability Information System)
Resource Conservation and Recovery Information System (RCRIS) Sites <sup>2</sup>	USEPA	Location of transfer, storage, and disposal facilities for solid and hazardous waste
Minerals Availability System/Mineral Industry Location System (MAS/MILS) <sup>2</sup>	U.S. Bureau of Mines	Location and characteristics of mining sites

<sup>1</sup>Data Layers that are added into the BASINS project using the Add Theme Tool.

<sup>2</sup>Data Layers that are added into the BASINS project using the Theme Manager Extension.

## 2.2 Environmental Assessment Tools

Three geographically based analytical tools were developed in the BASINS GIS environment to perform both regional and site-specific analyses --*TARGET*, *ASSESS*, and *Data Mining*. *TARGET* permits a broad-based analysis; *ASSESS* is a simple assessment tool that operates on a single watershed or a limited number of watersheds; and *Data Mining* lets BASINS users more fully access the water quality and point source databases. The three geographically based analytical tools are fully developed to operate on the water quality and point source data layers, as described in Section 2.3. BASINS operates on hydrologic units or watersheds as defined by the United States Geological Survey delineations referred to as “cataloging units.” These watersheds can vary in size from 10 square miles to several hundred square miles.

### **TARGET**

*TARGET* allows environmental managers to make a broad-based evaluation of a watershed’s water quality and/or point source loadings. This watershed targeting tool is designed to perform analysis on the entire area extracted (e.g., EPA regions, state) and is best suited for project areas that include more than one watershed (cataloging unit). *TARGET* is designed to integrate and process a large amount of detailed, site-specific data associated with a particular region and to summarize the results on a watershed basis. Using these water quality or point source loading summaries, watersheds are then ranked based on the level of selected evaluation parameters (e.g., DO, BOD, zinc). This analysis allows users to draw preliminary conclusions on the wide range of environmental data included in BASINS (e.g., 50 water quality parameters and most of the parameters associated with point source dischargers).

### **ASSESS**

The second geographically based tool uses the same data as *TARGET* but provides a different perspective on the locational distribution of potential pollution problems. *ASSESS* operates on a single watershed (cataloging unit) or a limited set of watersheds and focuses on the status of specific water quality stations or discharge facilities and their proximity to water bodies. This proximity analysis (stream reaches, water quality stations, point dischargers, land uses, etc.) is important because it allows analysts to establish the interrelationships between the condition of a water body in a watershed and potential pollution sources. The level of detail provided by *ASSESS* lets users visually focus on the status of specific stream reaches, assess their changes over time, evaluate data availability, and evaluate the need for source characterization and analysis of cause-effect relationships.

### **Data Mining**

*Data Mining* dynamically links different data elements using a combination of tables and maps. This unique dynamic linkage of data elements adds a significant informational value to the raw data on water quality and loadings. This process makes *Data Mining* a powerful tool that can assist in the integration and environmental interpretation of both geographic and historical information simultaneously. *Data Mining* complements both *TARGET* and *ASSESS* by letting users move progressively from a regional analysis (provided by *TARGET*) to a watershed-scale analysis (provided by *ASSESS*) to a more detailed analysis at the station level (provided by *Data Mining*). This logical progression of the analysis from regional to site-specific is illustrated in Figure 2.2.

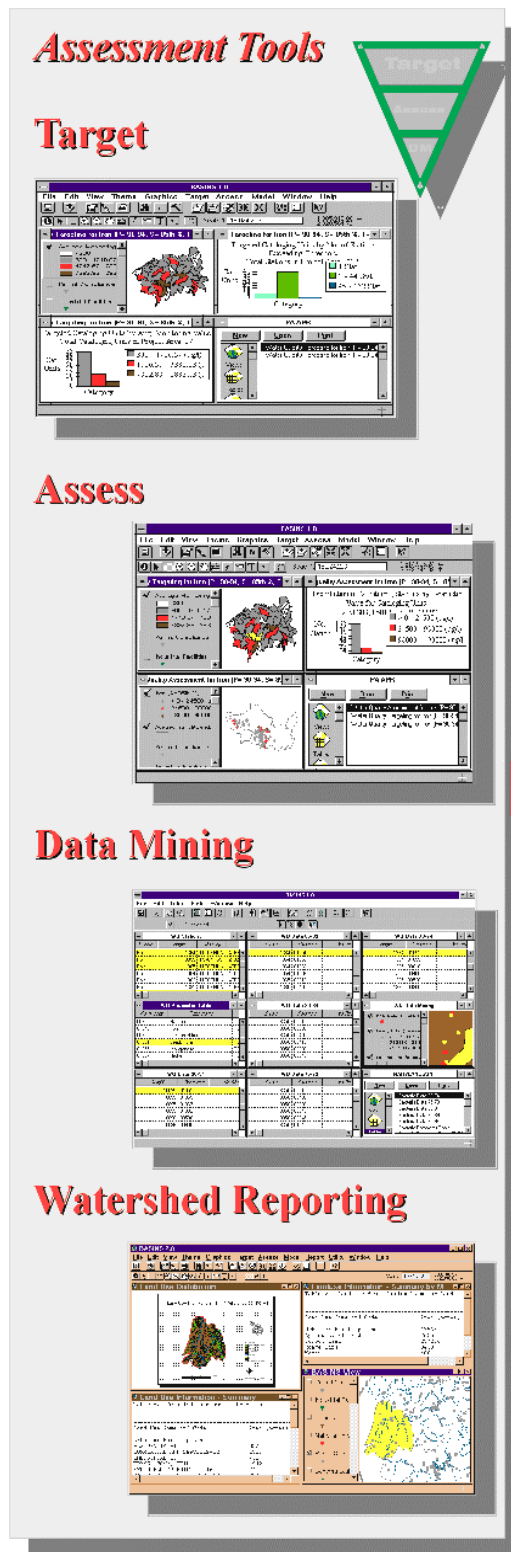


Figure 2.2

## 2.3 Utilities

### Theme Manager

The BASINS *Theme Manager* allows users to easily add or delete auxiliary data from a BASINS project. For BASINS 3.0, the BASINS databases were split into two groups of data, core data and auxiliary data. Auxiliary data are not directly used by any of the BASINS components.

### BASINS Import Tool

The BASINS *Import* tool gives the user the ability to import additional data sets and prepares the data to work properly with BASINS GIS functions and models. The *Import* tool is designed to function on five data types watershed boundaries, land use (shape and grid), Reach File Version 3, National Hydrography Dataset (NHD) and Digital Elevation Model (DEM) (shape and grid) format. This tool also provides the capability for users to import locally developed data, which might be more accurate, at a higher resolution, or more reflective of current conditions.

### NHD Download Tool

The *NHD Download* tool gives the user the ability to download a National Hydrographic Dataset (NHD) reach file directly from the USGS NHD ftp site and import the NHD reach file theme in the BASINS project using correct projection, preparing the data to work properly with BASINS GIS functions and models.

### Grid Projector

Grid Projector is a tool for conversion of ArcView/ArcInfo grid data between two map projections in ArcView environment. Grid Projector has capability for forward and inverse projection to and from a geographic reference (latitude-longitude) to several cartesian coordinates (feet, meters, etc.,).

### GenScn

GenScn facilitates the display and interpretation of output data derived from model applications. GenScn is not a model itself. It serves as a postprocessor for both the HSPF and SWAT models, as well as a tool for visualizing observed water quality data and other timeseries data.

### WDMUtil

WDMUtil is a utility program for managing Watershed Data Management (WDM) files, which contain input and output timeseries data for HSPF.

### Manual Delineation Tool

The BASINS *Manual Watershed Delineation* tool allows the user to delineate subwatersheds manually. It allows the user to subdivide a watershed into several smaller hydrologically connected watersheds based on the user's knowledge of that watershed's drainage topography. The tool also provides users the flexibility to edit shapes and attributes of manually delineated watersheds, outlets and generating stream networks.

### **Automatic Delineation Tool**

The BASINS *Automatic Watershed Delineation* tool allows the user to delineate subwatersheds based on an automatic procedure using Digital Elevation Model (DEM) data. User specified parameters provide limits that influence the size and number of subwatersheds created. This option requires the ESRI Spatial Analysis extension.

### **Predefined Delineation Tool**

The Predefined Delineation Tool is used to import existing subwatershed boundaries, streams, and outlets themes into the current BASINS project, for the purposes of watershed characterization and modeling.

### **Land Use, Soil Classification, and Overlay**

The Land Use, Soil Classification, and Overlay Tool allows the user to load land use and soil themes into the current project and determine the land use soil class combinations and distributions for the delineated watershed(s) and each respective sub-watershed. One or more unique land use/soil combinations (hydrologic response units or HRUs) can be created for each subbasin.

### **Land Use Reclassification**

The *Land Use Reclassification* tool assists the user in grouping or renaming land use categories as needed to support modeling and analysis. Land uses can be reclassified in one of two ways: reclassification of the entire theme (all land uses) or reclassification of selected themes (single or multiple land uses from within an entire theme).

### **Water Quality Observation Data Management**

The *Water Quality Observation Data Management* utilities can be used to access and manipulate the water quality observation data within the BASINS system. They can also be used to add new stations to the data, delete unnecessary stations, relocate misplaced stations, and incorporate new water quality observation time-series data.

### **DEM Reclassification**

*DEM Reclassification* performs topographic reclassification on a watershed. It allows users to define a level of detail for reclassification of Digital Elevation Model (DEM). It permits nonuniform reclassification to capture and display the key topographic features of the watershed. By assigning different classification intervals for the hilltop zone and valley zone, users can create suitable topographic classifications to describe the relief of the watershed they are evaluating.

### **Lookup Tables**

The *Lookup Tables* provide users quick access to relevant reference information on data products included within BASINS. Information is provided for products such as the map projection, definition of agency codes for monitoring data, Standard Industrial Classification (SIC) codes, and the water quality criteria and threshold values of selected pollutants.

## 2.4 Watershed Characterization Reports

The Watershed Characterization Reporting tools are designed to assist users in summarizing key watershed information in the form of standard and automated reports. These tools can be used to make an inventory and characterize both point and nonpoint sources at various watershed scales. The results are presented in table, chart and/or map layout formats. These reports allow users to quickly evaluate and define data availability for the selected watershed(s). Eight different types of watershed characterization reports are included in BASINS:

- Point Source Inventory Report
- Water Quality Summary Report
- Toxic Air Emission Report
- Land Use Distribution Report
- Land Use Distribution Report(Grid)
- State Soil Characteristics Report
- Watershed Topographic Report
- Watershed Topographic Report(Grid)

### **Point Source Inventory Report**

*Point Source Inventory Report* provides a summary of discharge facilities in a given watershed. The report relies on the EPA Permit Compliance System (PCS) database to identify permitted facilities in a selected study area and summarizes their discharge loading for a given pollutant. Application of this report tool provides rapid identification of permitted sources, the receiving water body segment (Reach File Versions 1 or 3), and a mapping function to display the geographical distribution of point sources in the study area.

### **Water Quality Summary Report**

*Water Quality Summary Report* provides a summary of water quality monitoring stations within the selected watershed that monitored a particular pollutant during a given time period. The water quality data are presented as statistical summaries of the mean and selected percentiles of the observed data. The data is based on USEPA's Storage and Retrieval System (STORET). The information generated in this report can be summarized in tables and maps.

### **Toxic Air Emission Report**

*Toxic Air Emission Report* provides a summary of facilities within the selected watershed(s) with air releases of selected pollutants. This data is based on USEPA's Toxics Release Inventory (TRI). Tabular summaries of TRI facilities are generated with their corresponding estimates of pollutant air releases and other pertinent information such as facility identification name, city location, status (active or inactive

facility), ownership type (government, commercial), and SIC code number. This report also generates a map showing the location of the TRI facilities overlaid with the Reach File network (RF1 or RF3) and the boundary of the selected watershed.

### **Land Use Distribution Report**

*Land Use Distribution Report* provides a summary of the land use distribution within the selected watershed(s). The BASINS default land use data is based on the USGS Geographic Information Retrieval and Analysis System (GIRAS) and use the Anderson Level II classification system.

### **Land Use Distribution Report (Grid)**

BASINS 3.0 allows the use of Grid based themes to generate a Land Use Distribution Report. This option needs the ArcView Spatial Analyst extension. The new Multi Resolution Land Cover (MRLC) data (grid format) can be used.

### **State Soil Characteristic Report**

*State Soil Characteristic Report* provides a summary of the spatial variability of selected soil parameters within the selected watershed(s). The soil parameters considered include water table depth, bedrock depth, soil erodibility, available water capacity, permeability, bulk density, pH, organic matter content, soil liquid limit, soil plasticity, percent clay content, and percent silt and clay content. The data is based on the USDA-NRCS State Soil and Geographic Database (STATSGO).

### **Watershed Topographic Report**

*Watershed Topographic Report* provides a statistical summary and distribution of discrete land surface elevations in the watershed. It also generates an elevation map of the selected watershed. This information can be used to quickly evaluate the relative “steepness” of the watershed compared to that of other watersheds and correlate it with the results of water quality modeling. The data is based on DEM (shape format) distributed with BASINS.

### **Land Use Distribution Report (Grid)**

BASINS 3.0 allows the used of Grid based themes to generate a Watershed Topographic Report. This option needs the ArcView Spatial Analyst extension. The DEM (grid format) which can be downloaded from the USGS ftp site and can be used to generate the report. The information generated in this report is summarized in table, chart and map layout formats.

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Tip: All reports that are created are stored under “Reports” GUI in the BASINS project. Use the *Show Report* submenu under the *Reports* menu to selectively view generated reports. This feature allows the user to view generated reports while in BASINS “View” without having to switch to the “Reports” section of the BASINS project. Note the *Show Report* submenu is part of the “Reports without Spatial Analyst” extension.

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## 2.5 Watershed and Instream Models

Three models are integrated into BASINS to allow the user to simulate the in-stream behavior of toxic chemicals, conventional pollutants, and nutrients. The models included were selected to allow users to assess in-stream water impacts at various levels of complexity. Data preparation, selection routines, and output display tools (for visualization) streamline the use of the models.

### QUAL2E

The *QUAL2E* model is provided to allow analysis of pollutant fate and transport through selected stream systems. It is a one-dimensional water quality model that assumes steady-state flow but allows simulation of diurnal (day-night) variations in temperature, algal photosynthesis, and respiration (Brown and Barnwell, 1987). The algorithms used in *QUAL2E* are based on the advection-dispersion mass transport equation solved using an implicit, backward difference scheme, averaged over time and space. *QUAL2E* represents the stream system as a series of computational elements of constant length. The model is integrated with BASINS through a Windows-based interface, and it allows fate and transport modeling of both point and nonpoint source loadings.

### HSPF

*HSPF* is a watershed model that simulates nonpoint source runoff and pollutant loadings for a watershed and performs flow and water quality routing in reaches. The Windows interface to HSPF, known as *WinHSPF*, works with the EPA-supported HSPF model (version 12.0) (Bicknell et al., 2000). *WinHSPF* supports a full suite of the HSPF model capabilities. Features supported by *WinHSPF* include:

- Estimation of nonpoint source loadings from mixed land uses
- Estimation of fate and transport processes in streams and one-dimensional lakes

*WinHSPF* can be run on a single watershed or a system of multiple hydrologically connected subwatersheds that have been delineated using the BASINS *Watershed Delineation* tool. The model requires land use data, reach data, meteorological data, and information on the pollutants of concern in the watershed and the reaches. *WinHSPF* is designed to interact with the BASINS utilities and data sets to facilitate the extraction of appropriate information and the preparation of model input files. The reach network is automatically developed based on the subwatershed delineations. Users can modify and adapt input files to site-specific conditions through the use of *WinHSPF* and supporting information provided by the BASINS utilities and reporting functions, as well as locally derived data sources. *WinHSPF* works with postprocessing tools to facilitate display and interpretation of output data.

### SWAT

The Soil and Water Assessment Tool (SWAT) is a physical based, watershed scale model that was developed to predict the impacts of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land uses and management conditions over long periods of time. SWAT was developed by the USDA Agriculture Research Service (ARS).



## **PLOAD**

PLOAD is an ArcView extension developed by CH2M HILL for calculating pollutant loads for watersheds. The application estimates nonpoint sources of pollution on an annual average basis, for any user-specified pollutant, using either the export coefficient or simple method approach. PLOAD was designed to be generic so that it can be applied as a screening tool in typical NPDES stormwater permitting, watershed management, or reservoir protection projects.

## **GenScn Postprocessor**

BASINS includes the program *GenScn*, originally developed by the U.S. Geological Survey, which facilitates the display and interpretation of output data derived from model applications. This tool allows users to select display locations and time periods. Displays are in graphical and tabular form. *GenScn* displays a variety of data formats, including *HSPF* simulation output, BASINS water quality observation data, and USGS flow data, and SWAT output data. It also performs statistical functions and data comparisons. Due to its ability to display and compare observed and modeled data, the postprocessor is a useful tool in model calibration and environmental systems analysis.

